NHTSA's Light Vehicle ESC Research Program

June 9, 2005

Dr. W. Riley Garrott
Garrick J. Forkenbrock

National Highway Traffic Safety Administration
Vehicle Research and Test Center

Effectiveness of Electronic Stability Control for Preventing Crashes

ESC Effectiveness

- Multiple studies have been conducted
- Europe
  - DaimlerChrsyler
  - Swedish Nat. Road Administration
  - European Accident Causation Survey
- Japan
  - Toyota
- United States
  - NHTSA
  - IIHS

DaimlerChrsyler

www.nhtsa.dot.gov
nhtsa
people saving people

- German crash data
  - German Government Statistics Office (Statistischen Bundesamtes)
  - 1999/2000 data compared to 2000/2001
    - Newly registered Mercedes vehicles
    - ESC standard equipment for MY1999
- Estimates based on statistical analyses
  - 15% reduction in total accidents
  - 30% reduction in single vehicle accidents
- Reductions in side-impacts, rollover crashes, and average injury severity

Swedish Nat. Road Administration
(Tingvall, et al.)

- **Swedish crash data**
  - **Police reported accidents with at least one injured person**
  - **Accidents occurred during 2000 to 2002**
  - **Cars of similar/identical make model were used; 1998 to 2003 model years**
- **ESC effectiveness estimates based on statistical analyses**
  - **Dry roads: No significant effect**
  - **Wet roads: At least a 7.8% reduction***
  - **Snow / Ice: At least a 12.1% reduction***
- **Most significant accident reduction observed for large cars (both front- and rear-wheel drive), especially on low-mu surfaces**

Lower bound of the 95% confidence limit

European Accident Causation Survey (Sferco, et al.)

www.nhtsa.dot.gov
nhtsa
people saving people

- Potential ESC effectiveness based on statistical analyses of EACS data (i.e., the "opportunity" for ESC to improve safety)
- EACS contains data from approximately 1674 crashes in 5 European countries from 1995 to 1999
- Expert EACS investigators believe the presence of ESC could have improved the outcome of many accidents investigated
  - Injury accidents: 18%
  - Fatal accidents: 34%
- If accident causation was "loss of vehicle control", the benefits of ESC are expected to be even more apparent
  - Injury accidents: 42%
  - Fatal accidents: 67%

Toyota (Aga, et al.)

www.nhtsa.dot.gov
nhtsa
people saving people

- Japanese crash data
  - Compiled by the Institute for Traffic Accident Research and Data Analysis (ITARDA)
  - 3 popular Toyota passenger cars were considered
- Estimates based on statistical analyses
  - 35% reduction in single car accidents
  - 30% reduction in head-on collisions with other vehicles
  - 35% reduction in casualties per year
    (for single car crashes and head-on collisions)
- ESC effectiveness appears to be highest in the range of approximately 40 - 100 kmph (25 – 75 mph)

NHTSA (Dang)

www.nhtsa.dot.gov
nhtsa
people saving people

- Examined single vehicle crashes
  - Limited number of higher end vehicles
- Two sources of data
  - State data for all crash severities for five states (1997 – 2002)
  - FARS data (1997 –2003)
- All severities of single vehicle crashes reduced
  - Passenger cars: 35%
  - Sport utility vehicles: 67%
- Fatal single vehicle crashes reduced by:
  - 30% for passenger cars
  - 63% for sport utility vehicles

Insurance Institute for Highway Safety

- Calculated fatal crash risk per registered vehicle for vehicles with ESC standard versus those with no ESC or ESC optional
- Found that:
  - Fatal single vehicle crash risk reduced by 56%
  - Multi-vehicle fatal crash risk reduced by 17%
  - Risk for all fatal vehicle crashes reduced by 34%
- If ESC present on all light vehicles, it could
  - Prevent 800,000 single vehicle crashes per year
  - Saving 7,000 lives per year

ESC Effectiveness - Summary

- Multiple studies, in several countries using different data sets and methodologies, have all found substantial reduction in single vehicle crashes due to ESC
  - Typically about a 30% reduction
- Each study indicates installation of ESC on all light vehicles should prevent many fatal crashes each year

How Does Electronic Stability Control Prevent Crashes?

How ESC Helps:
Untripped Rollover Reduction

www.nhtsa.dot.gov
nhtsa
people saving people

- Test using NHTSA Fishhook
- ESC can be tuned to prevent two wheel lift in NHTSA Fishhook
  - Not all tunings will prevent untripped rollover
  - Requires aggressive front wheel braking
- Untripped rollovers represent a small percentage of the rollover crash problem

How ESC Helps:
Transient Oversteer Reduction

www.nhtsa.dot.gov

nhtsa people saving people

- **Test using variant of single sine steer**
  - **Will discuss test in greater detail later**
  - **NHTSA has selected**
- **Thought to be important mechanism for prevention of crashes**
  - **Approximately 25% of fatal single vehicle crashes believed to be due to transient oversteer**

Example:
Transient Oversteer (disabled ESC)

www.nhtsa.dot.gov
nhtsa
people saving people

2004 Volvo XC 90
ESC Disabled
SWA = 130 degrees

Example:
Effect of ESC (enabled ESC)

www.nhtsa.dot.gov
people saving people

2004 Volvo XC 90
ESC Enabled
SWA = 300 degrees

How ESC Helps:
Excessive Understeer Reduction

www.nhtsa.dot.gov
nhtsa
people saving people

- **Do not know how to test for excessive transient understeer**
  - **Plan to develop test in future**
- **Thought to be important mechanism for mitigation or prevention of crashes**
  - **Magnitude of effect not known**

How ESC Helps: *Slows Vehicle Down*

- **ESC gets brakes on in emergency situations**
  - Generally, this is better than not braking
- **ESC may also "pre-charge" a vehicle's brakes**
  - Low pressure brake application
  - Gets brakes on 0.10 to 0.15 seconds faster if needed
- **Thought to be important mechanism for mitigation or prevention of crashes**
  - Even small amount slowing down can mitigate or prevent some crashes
  - Magnitude of effect not known

How ESC Helps:

- We do not have complete answer to question of how ESC helps
- Remains active research topic

Current NHTSA ESC Research Program

Program Objectives

- Develop test to ensure that vehicle does not go out of control (spinout) due to transient oversteer
  - Objective satisfied, will discuss later
- Develop pass/fail criteria
- Prevention of excessive understeer will be worked upon later
- May or may not want to do further research on how ESC helps slow vehicles down

Program Approach

www.nhtsa.dot.gov
nhtsa
people saving people

- **Building on non-linear handling research performed by Alliance of Automobile Manufacturers**
- **NHTSA is collaboratively gathering data to improve proposed test to ensure that vehicle does not spinout due to transient oversteer**
  - **Presently refining pass/fail criteria**

Five Maneuvers
Performed With A Steering Machine

www.nhtsa.dot.gov
nhtsa
people saving people

- **Slowly Increasing Steer**
  (for characterization use only)
- **0.7 Hz Sine with Dwell**
- **0.7 Hz Increasing Amplitude Sine**
- **500 deg/s Yaw Acceleration Steering Reversal**
- **500 deg/s Yaw Acceleration Steering Reversal w/Pause**

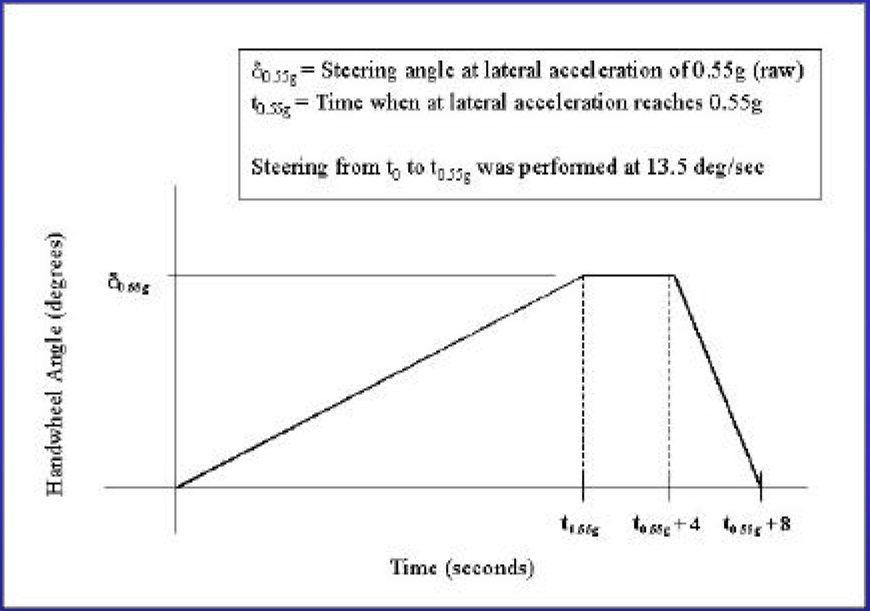
Test Conditions

www.nhtsa.dot.gov
nhtsa
people saving people

- ESC enabled and disabled
- Test surface
  - Dry, high-mu asphalt
  - Maneuvers initiated while vehicle is being driven up a 1% grade
- Nominal load
  - Driver
  - Instrumentation
  - Outriggers if vehicle is an SUV, pickup, van, minivan, station wagon, or crossover vehicle

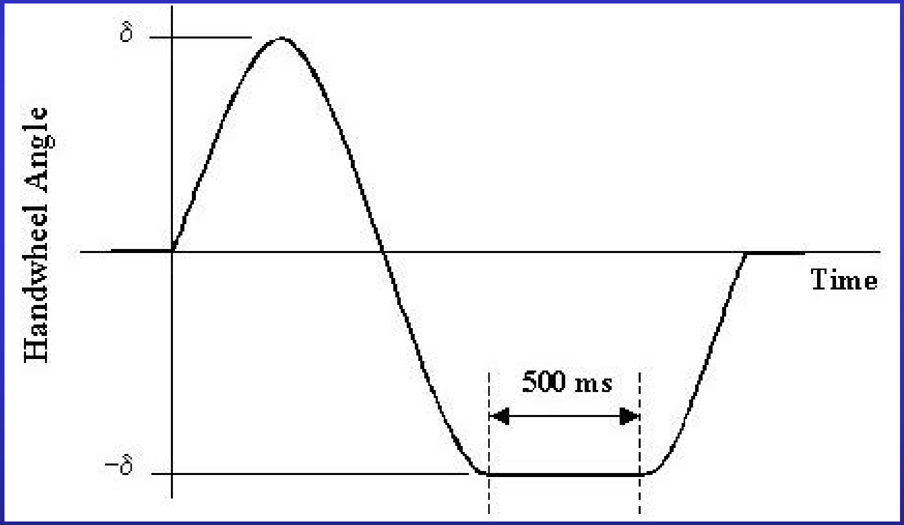
Maneuver Description
Slowly Increasing Steer

- **Low severity**
  - **Used for characterization only**
  - **Raw AY of 0.55g**
- **Provides the SWA at 0.3g**
  - **Data is required by all other maneuvers performed in this study**
  - **Must first be corrected for roll effects**
- **Driver attempts to maintain constant vehicle speed via throttle modulation**
  - **50 mph**



Maneuver Description
0.7 Hz Sine with Dwell

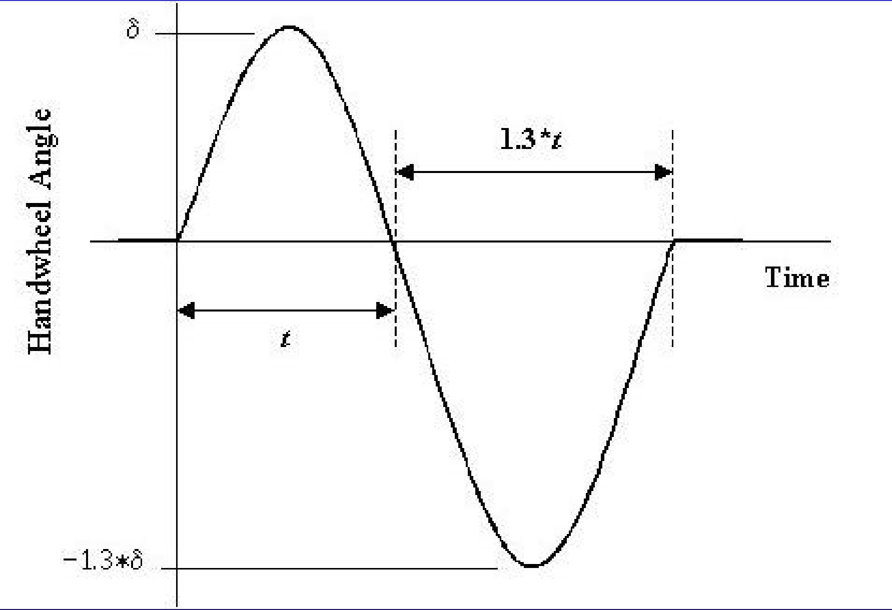
- **Steering frequency fixed at 0.7 Hz, but with a 500 ms pause after the 3rd quarter-cycle**
- **Severity increased with SWA**
  - **Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater**
- **50 mph entrance speed**
- **Dropped throttle**



Maneuver Description
0.7 Hz Increasing Amplitude Sine

- Steering of frequency first ½ cycle fixed at 0.7 Hz
- 2nd ½ cycle amplitude is 1.3 times that of the 1st ½ cycle
- Duration of the 2nd ½ cycle is 1.3 times that of the 1st ½ cycle
- Severity increased with SWA
  - Increments of 1.0*$d_{\text{0.3g AY from SIS}}$,
  - Lowest 2nd Steer SWA: 1.5*$d_{\text{0.3g AY from SIS}}$,
  - Highest 2nd Steer SWA: 270 deg or 6.5*$d_{\text{0.3g AY from SIS}}$, whichever is greater

- 50 mph entrance speed
- Dropped throttle

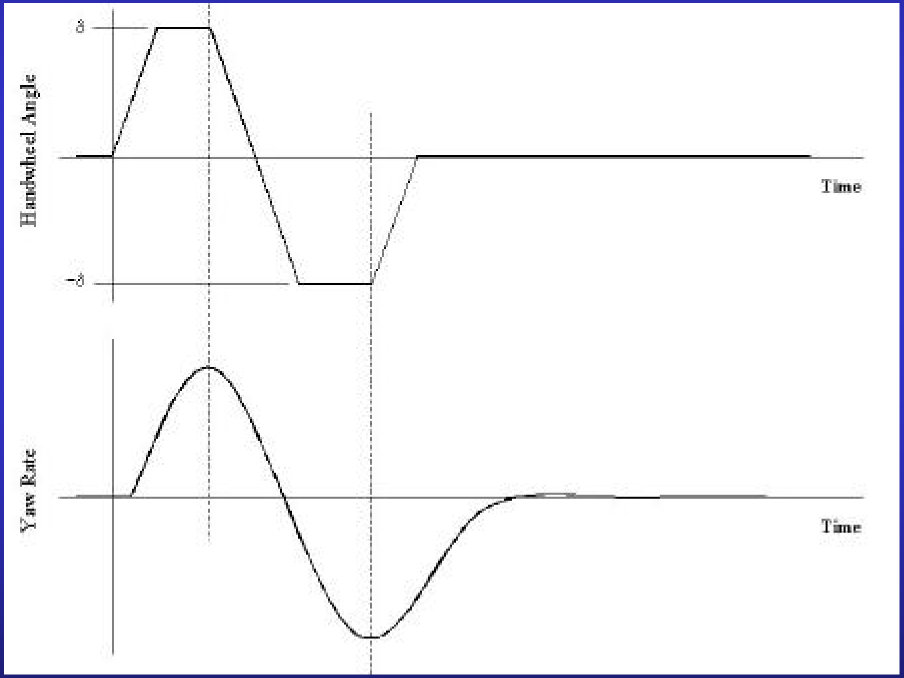


Maneuver Description

Yaw Acceleration Steering Reversal

www.nhtsa.dot.gov
nhtsa
people saving people

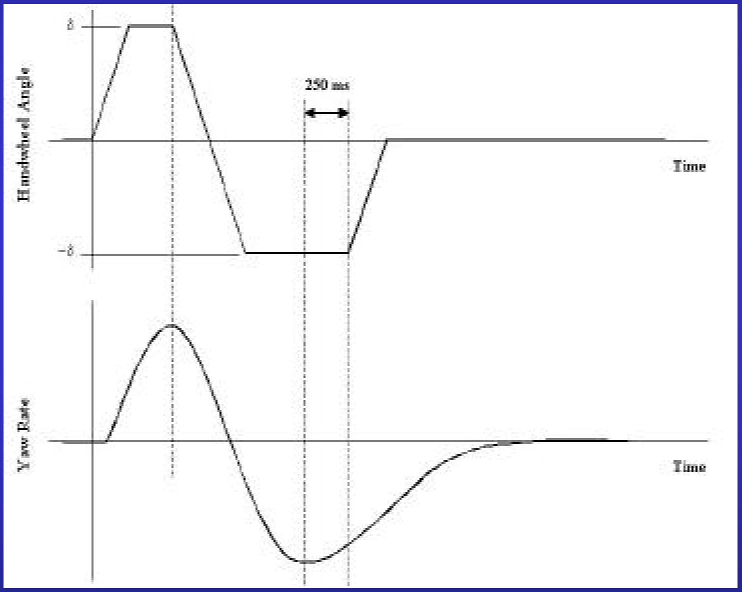
- **Maneuver adapts to the vehicle being evaluated rather than relying on one frequency**
- **Steering reversals both initiated at peak yaw rate**
- **Severity increased with SWA**
  - **Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater**
  - **500 deg/s ramp rates**



Maneuver Description

Yaw Accel Steering Reversal w/Pause

- Maneuver adapts to the vehicle being evaluated rather than relying on one frequency
- 1st steering reversal initiated at peak yaw rate, 2nd reversal at peak yaw rate + 250 ms
- Increased dwell after second yaw rate peak gives the vehicle more time to respond to the second peak SWA
- Severity increased with SWA
  - Increments of 1.0*$d_{0.3g\text{ AY from SIS}}$,
  - Lowest SWA: 1.5*$d_{0.3g\text{ AY from SIS}}$,
  - Highest SWA: 270 deg or 6.5*$d_{0.3g\text{ AY from SIS}}$, whichever is greater
  - 500 deg/s ramp rates



Program Approach

- Each of these maneuvers has advantages and disadvantages
  - Much emphasis was placed on better understanding these factors for each maneuver
- Recently, the “Sine with Dwell” was selected as NHTSA’s preferred test maneuver
- Results from NHTSA and industry indicate this maneuver offers the best combination of severity, performability, and repeatability for a broad range of vehicles

2005 Testing

- **Evaluate 50 vehicles in 2005**
  - **NHTSA: 24 vehicles**
  - **Industry: 26 vehicles**
- **Vehicles separated into two groups**
  - **Priority #1**
  - **Priority #2**
- **Data from “Priority #1” vehicles presently being analyzed**
- **NHTSA hopes to have a more well-defined pass/fail criteria by July 1, 2005**

Pass/Fail Criteria

- **Spinout must not occur**
  - **Need definition of spinout**
- **Vehicle must still be responsive**
  - **E.g., Must achieve a minimum lateral displacement during test**
  - **Proposed magnitude: 12-feet**
- **No two-wheel lift**
- **No tire debeading or rim-to-pavement contact**

What is a "Spinout"

- NHTSA does not know of a generally accepted, quantitative definition
- People generally know spinout when they see it
- However, there are some vehicles/cases which are not clear

What is a “Spinout”

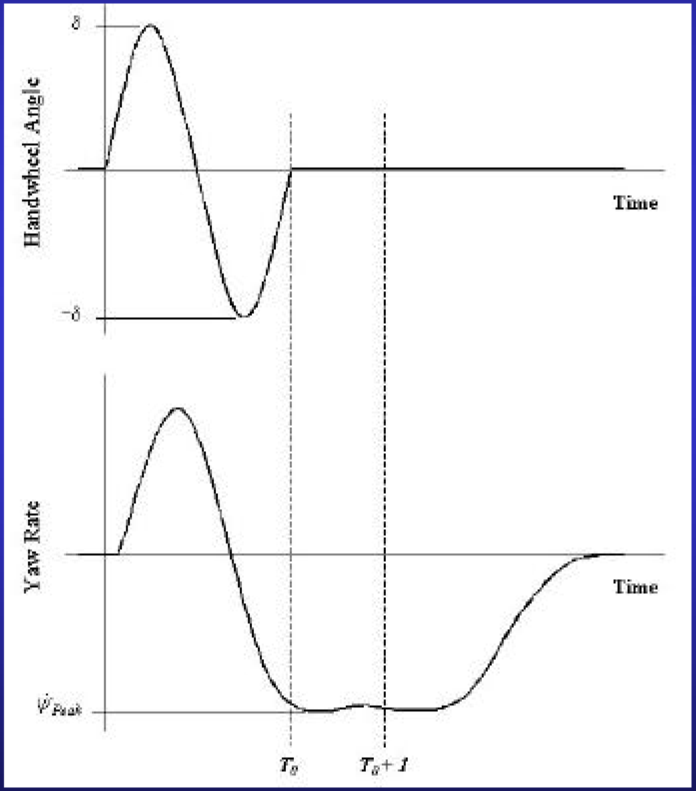
What is a "Spinout"
Preliminary NHTSA Definition

www.nhtsa.dot.gov nhtsa people saving people

$$Percent\ \dot{y}_{Peak} = 100 * \left(\frac{\dot{y}(t)}{\dot{y}_{Peak}} \right)$$

$$Set\ t = t_0 + 1$$

$$Spinout\ occurs\ if\ \ Percent\ \dot{y}_{Peak} \geq 60\%$$



What is a "Spinout"

www.nhtsa.dot.gov
nhtsa
people saving people

- **Other people/organizations are developing alternative definitions of spinout**
  - **NHTSA welcomes alternate definitions!**
- **Will pick the best, most robust definition from among those suggested**

Additional Information on NHTSA's Research

- **ESC Docket**
  - **http://dms.dot.gov/search/searchFormSimple.cfm**
  - **Number 19951**
- **VRTC ESC Website**
  - **http://www-nrd.nhtsa.dot.gov/vrtc/ca/esc.htm**